Progress Report (5/12/95 - 4/30/96)

for

The NASA Grant NAG5-2930

entitled

Analyses for the Climatology and Short-term Variability of the Atmospheric Circulation with the GLA GEOS-Data: Global Hydrological and Energy Cycle

Principal Investigator:
Tsing-Chang (Mike) Chen
Atmospheric Science Program
Iowa State University

1. Progress

In the fiscal year, five studies were pursued with the GLA GEOS data for (1) variability of the global precipitable water, (2) hydrological processes associated with cyclones , (3) rainfall of Mexican monsoon, (4) 30-60 day variation of atmospheric angular momentum and (5) interannual variation of atmospheric circulation. The result of these studies are summarized as follows:

1. Variability of the global precipitable water

A 90-150 day signal is identified in the global precipitable water field generated by the Global Data Assimilation Systems (GDAS) of the Goddard Laboratory for Atmospheres (GLA), National Meteorological Center, and European Centre for Medium-Range Weather Forecasts. The finding of this intraseasonal signal in global precipitable water is significant for two reasons: (1) it suggests that there is 90-150 day intraseasonal variability in the atmospheric branch of the global hydrological cycle and (2) it provides a useful parameter to test the sensitivity of the GDAS-generated hydrological data. This newly identified intraseasonal signal in the global precipitable water was verified with Special Sensor Microwave/Imager precipitable water data over oceans and station-mixing ratio data over the continental United States. Based upon some simple statistical analyses and global and regional composite charts, it was found that the 90-150 day low-frequency oscillations contained in different GDAS data sets are more coherent with each other in regions with good data coverage but are poorly correlated over the data-sparse area. Furthermore, the GLA GDAS provides the most realistic representation of this intraseasonal global precipitable water signal.

2. Hydrological processes associated with cyclones

A substantial amount of precipitation in the midlatitudes occurs in association with extratropical cyclones. Using the data generated by version 1 of the Goddard Earth Observing System (GEOS-1) Data Assimilation System for 1985-1989, we analyzed hydrological processes and the water vapor budget over the U.S. to illustrate the maintenance of precipitable water and precipitation associated with extratropical cyclones. The area-mean divergence of water vapor flux covering the Great Plains and the eastern region of the U.S. (80°W - 105°W, 30°N - 50°N) was adopted as a hydrological index. The cyclones over this region that have values of this index smaller than minus one standard deviation over a season were selected for analysis. On average,

15 cases were selected for each season. The composite results show a developing baroclinic wave coupled with a low-level cyclone in which the low-level convergent (divergent) center and the upper-level divergent (convergent) center ahead of the trough (ridge) are linked by an upward (downward) branch of the divergent circulation, consistent with the classical cyclone model. Thus, water vapor converges (diverges) through the low-level divergent circulation of the cyclone wave to maintain precipitation (evaporation) centers ahead of the trough (ridge). It is estimated that the amount of water vapor accumulating in the Great Plains and the eastern U.S. throughout winter (November-March) could be converged by typical cyclones within a month. During summer (May-September), it would take only about a half month for typical cyclones to converge water vapor toward this region sufficient to account for the summer-season runoff by streamflow over this region.

3. Rainfall of Mexican Monsoon

Three aspects of the relationship between the Mexican monsoon and the summertime large-scale circulation were examined: seasonal evolution, interannual and intraseasonal variations. The major findings of this study are as follows: (1) The onset of the Mexican monsoon occurs when the cold dry northwesterlies over the monsoon region are reversed to warm moist southeasterlies. The reversal of the low-level monsoon flow follows the northward seasonal migration of the North-Pacific and North-Atlantic anticyclones. (2) As indicated by the NINO-3 SST anomalies, the tropical Pacific condition was anomalously warm in the 1987 summer and anomalously cold in the 1988 summer. A teleconnection-like stationary wave train was induced by the anomalous SST condition in the early summer of both years. At the eastern end of this wave train, a low-level anomalous low (high) appeared in the early summer of 1988 (1987). Compared to 1987, the onset of monsoon rainfall was about one month earlier in 1988. This early monsoon onset resulted from the appearance of the anomalous low adjacent to the monsoon region. (3) The seasonal variation of the Mexican monsoon is modulated by two intraseasonal (30-60 and 10-24 day) monsoon modes. The 30-60 day monsoon mode, which is continental-scale, induces westerly (easterly) anomalies during the weak (strong) monsoon, while the regional-scale 10-24 day monsoon mode significantly affects the regional monsoon rainfall. Moreover, the 10-24 day mode may also be intensified (weakened) by the 30-60 day oscillation during the strong (weak) monsoon.

4. 30-60 day variation of atmospheric angular momentum

The existence of the intraseasonal variation of relative atmospheric angular momentum and the poleward propagation of this physical quantity by the intraseasonal mode of atmospheric circulation has been amply demonstrated in previous studies. However, the temporal relationship between the intraseasonal variation and poleward propagation is not well understood and the possible mechanism causing the poleward propagation is unknown. Analyzing the 15-year (1979-1993) upper-air data of the National Meteorological Center, we explored these two intriguing issues related to atmospheric angular momentum via case-study analyses. The major findings are as follows:

(a) The maximum (minimum) 30-60 day globally-integrated atmospheric angular momentum occurs when the positive (negative) angular momentum anomalies of a 30-60 day cycle appear in the tropics-subtropics and those of the previous 30-60 day cycle propagate to the northern and southern midlatitudes.

(b) The eastward propagation of the 30-60 day global divergent circulation induces a 30-60 day flip-flop oscillation in the meridional circulation which in turn results in a similar alternation in the angular momentum tendency caused by the Coriolis torque. It was inferred from the zonal-mean angular momentum budget analysis that the 30-60 day variation of atmospheric angular momentum and its poleward propagation are a result of the 30-60 day variation of the aforementioned momentum tendency.

5. Interannual variation of atmospheric circulation

A simple diagnostic scheme, which combines a low-pass temporal filter (with an 18-month cutoff time) with a regular empirical orthogonal function (EOF) analysis, is used to delineate the synchronous evolution of ENSO-related modes in various variables of the ocean-atmosphere system. Based on the causal relation chain of diabatic heating, divergent circulation and rotational flow, the diagnostic scheme extracts ENSO modes from the following data sources: the Pacific sea surface temperature (SST), the past 14-years (1979-1992) of data generated by the Global Data Assimilation System of the National Meteorological Center, and a 10-year (1979-1988) general circulation model climate simulation made at the Goddard Laboratory for Atmospheres. The analysis reveals the following: (a) the eigencoefficient time series of the first eigenmodes of selected filtered variables, which explain about 40 - 50% of their total variance, synchronize with the filtered SST averaged over Area NINO-3; (b) the spatial structures of the first eigenmodes resemble the ensemble departures associated with ENSO events of these variables from their long term means; and (c) the results show that the proposed scheme can be easily applied to isolate and illustrate the time evolution of ENSO modes which exist in the long term observational data base as well as in climate simulations.

II. Publication

1. Chen, T .-C., J. Pfaendtner, J.-M. Chen and C. K. Wikle, 1995: Variability of the global precipitable water with a time scale of 90-150 day. *J. Geophys. Res.* (In press)

2. Chen, T.-C., M.-C. Yen, and S. Schubert, 1995: Hydrological processes associated with the extratropical cyclone systems over the US. *Bull. Amer. Meteor. Soc.*, (In press)

3. Chen, T.-C., and J.-M. Chen, 1995: Mexican monsoon: Its relationship with the summertime large-scale circulation. *J. Climate* (pending review)

4. Chen, T.-C., and S.-P. Weng, 1995: The poleward propagation of atmospheric angular momentum with a 30-60 day time scale. *Dynamics of Atmosphere and Ocean* (pending review)

5. Chen, T.-C., M.-C. Yen, J. Pfaendtner and Y. C. Sud, 1995: An alternative depiction of the interannual variation of atmospheric circulation associated with ENSO events. *Atmosphere-Ocean.* (In press)

III. Future Study

Three research tasks were proposed in this project:

1. The climatology and low frequency variability of global and regional hydrological processes,
2. the global energy cycle,
3. the interhemispheric exchange of angular momentum and heat under these three research tasks.

We are pursing the following subjects:

1. The annual variation of atmospheric airmass and water vapor budget,
2. the coupling of the global energy cycle and the refresh water, cycle of oceans,
3. the angular momentum budget analyses of a newly-identified 70-120 day mode.

These studies will be accomplished within the next funding year (5/1/96 - 4/30/97).

IV. Personnel involved in the project

Dr. Tsing-Chang (Mike) Chen - PI
Dr. Siegfried Schubert - current collaborator, the Goddard Data Assimilation Office
Dr. James Pfaendtner - former collaborator, the Goddard Data Assimilation Office
Dr. Ming-Chen Yen - postdoc research associate, Iowa State University
Dr. Jau-Ming Chen - postdoc research associate - Iowa State University
Mr. Chris K. Wikle - Ph.D. candidate, Iowa State University
Mr. Shu-Ping Weng - Ph.D. candidate, Iowa State University
Dr. Y. C. Sud - collaborator, the Goddard Radiation and Climate Branch